

Citation for published version:

Chowdhury, SM & Wandschneider, F 2018, Anti-trust and the 'Beckerian Proposition': the Effects of Investigation and Fines on Cartels. in V Tremblay, E Schroeder & C Tremblay (eds), *Handbook of Behavioral Industrial Organization.*, 14, Edward Elgar Publishing Ltd, pp. 368-403. <<https://www.elgar.com/shop/handbook-of-behavioral-industrial-organization>>

Publication date:
2018

Document Version
Peer reviewed version

[Link to publication](#)

This is a draft chapter / article. The final version is available in Handbook of Behavioral Industrial Organization edited by Victor Tremblay, Elizabeth Shroeder and Carol Tremblay, published in 2018, Edward Elgar Publishing Ltd <http://dx.doi.org/10.4337/978XXXXXXXXXX.000XX>
The material cannot be used for any other purpose without further permission of the publisher, and is for private use only.

University of Bath

Alternative formats

If you require this document in an alternative format, please contact:
openaccess@bath.ac.uk

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Antitrust and the 'Beckerian Proposition': the Effects of Investigation and Fines on Cartels^{*}

Subhasish M. Chowdhury ^a and Frederick Wandschneider ^b

^a School of Economics, Centre for Behavioural and Experimental Social Science, and Centre for Competition Policy, University of East Anglia, Norwich NR4 7TJ, UK

^b CEG Europe, Königsallee 92A, 40212 Düsseldorf, Germany

This version: 30 January 2017

Abstract

To deter and punish illegal collusions antitrust authorities run costly investigations and levy fines on detected and convicted wrongdoers. According to Becker (1968) the magnitude of fines and the detection rates are substitutable in their deterrence effect. We investigate this proposition through a market experiment, and study the effects of different fine and detection rate combinations (with constant expected fines) on cartel activity, prices and cartel stability. Our results show that in the absence of a leniency program, complying with the *Beckerian Proposition*, detection rates and fines are indeed substitutable in deterring cartels. With a leniency program, however, due to behavioral bias a regime that embodies low detection rate and high fine lowers the overall incidence of cartelization. The market price in this regime is also significantly lower than in a high detection rate low fine regime. Finally, irrespective of the presence of a leniency program, the different detection rate – fine combinations do not affect the cartel stability. These findings indicate that antitrust agencies can rely on behavioral biases to economize on enforcement costs and achieve a higher degree of deterrence by reducing investigative efforts and increasing the fine level.

JEL Classification: C92; D03; K42; L4

Keywords: Experiment; Antitrust; Cartels; Deterrence; Leniency

Corresponding author: Subhasish M. Chowdhury (s.modak-chowdhury@uea.ac.uk)

^{*} We thank the Editors, David Cooper, Steve Davies, Stephen Martin, Franco Mariuzzo, Johannes Paha, Russell Pittman, Adriaan Soetevent, Giancarlo Spagnolo, the seminar participants at the Korea Development Institute, Jadavpur University, University of East Anglia, and participants at the NIBS Conference in Nottingham, MaCCI Conference in Mannheim, London Experimental Workshop, World Meetings of the Economic Science Association in Zurich, CeDex-CREED-CBESS meeting in Amsterdam, 7th CLEENWorkshop in Bergen for useful comments, and Melanie Parravano for assistance in the lab. Financial support for the experiment was provided by the ESRC Centre for Competition Policy, University of East Anglia. All opinions and errors are ours alone.

“Whatsoever evil it is possible for man to do for the advancement of his own private and personal interest at the expense of the public interest, that evil, sooner or later, he will do, unless by some means or other, intentional or otherwise, prevented from doing it.”

- Jeremy Bentham (1830)

1. Introduction

Bentham’s wisdom, from almost two centuries ago, is still relevant for all aspects of criminal behavior. Hence, deterrence of such behavior is still an important issue. Becker (1968) makes a seminal contribution in this aspect that is often termed as the ‘Beckerian Proposition’. The Proposition assumes that criminals are perfectly rational. This means that individuals base their decisions on expected benefits and costs. The expected cost $[E(C)]$ of crime equals the probability of apprehension/conviction (ρ) times the fine (\mathbb{F}): $E(C) = \rho\mathbb{F}$. For the rational criminal only the expected cost matters and hence ρ and \mathbb{F} are perfectly substitutable. That is, crime deterrence is the same for any ρ and \mathbb{F} combination that produces the same $E(C)$.

Consider the specific case of a market where illegal collusion is possible. A central task of antitrust authorities there is to prevent firms from wrongdoing. The authorities do so by imposing fines on detected cartel members. A fully rational or self-interested firm will be affected only by the expected cost of litigation. To deter firms from engaging in misconduct, it is necessary that the expected cost of collusion exceeds the economic gains from participating in the same (cf. Ehrlich, 1973). As the economic gain, in general, lies outside the direct control of antitrust legislation, policy makers are left with the expected cost that can be manipulated in two ways: increase the likelihood of detection, or increase the severity of the imposed fine.

According to the Beckerian Proposition stated above, the magnitude of fines and the likelihood of detection are substitutable in their deterrence effect and hence it is optimal to impose a high level of fines with minimal investment in costly detection. In this study we examine this Proposition by means of a market experiment, and investigate how the magnitude of the fine levied on a firm and the likelihood of antitrust punishment affect the choice to participate and engage in an illegal cartel. It is important to test this, since evidence from behavioral economics indicates that the behavior of economic agents is not always perfectly rational.¹ A common finding is that

¹ For a review of the evidence, see Camerer and Loewenstein (2004) and Angner and Loewenstein (2007). For a discussion of the link between behavioral economics and antitrust, see Bailey (2015).

some people make errors when dealing uncertain events (i.e., settings that involve probabilities).² For boundedly rational individuals (Simon 1955; Spiegler, 2011), fines may be easier to understand than probabilities. If subjects suffer from this form of cognitive limitation, then \mathbb{F} and ρ would not be perfect substitutes; subjects may put more weight on \mathbb{F} than ρ . Thus, one of the goals of this chapter is to test the hypothesis that subject behavior is consistent with perfect rationality, such that \mathbb{F} and ρ are perfect substitutes. If this hypothesis is rejected, it suggests that subjects in this study suffer from behavioral bias.

These analyses have very many practical implications. Antitrust authorities in different countries are recently experimenting to find an optimal punishment for antitrust infringements. In the United States the Sentencing Commission is undertaking a review of its sentencing guidelines with a focus on corporate fine provisions, and the UK Competition and Market Authorities' chief executive announced a "*robust programme of enforcement, which includes imposing serious penalties on infringing businesses where appropriate*", which will "*seek to maximize the deterrent effect of this activity*" (CMA, 2014).³

The reasoning behind such a policy movement is simple: the antitrust authorities economize on the cost of enforcement by committing fewer resources to the detection of a crime, while aiming to achieve the same deterrence effect through an offsetting increase in the fines levied upon wrongdoers. This relates to the aforementioned Beckerian Proposition. This area of academic literature begins with Becker (1968) and is extended to risk-averse agents by Polinsky and Shavell (1979). Most recently Dhami and al-Nowaihi (2013) use a non-expected utility framework and show that the Beckerian Proposition holds also under rank-dependent utility and cumulative prospect theory.⁴

The application of the Beckerian Proposition in antitrust policy, phrased by Kolm (1973) as "*hang offenders with probability zero*", is not uncontested. Block and Sidak (1980), for

² Many examples can be found in Kahneman and Tversky (1981), Korobkin and Ulen (2000), and Lee and McCrary (2006).

³ Other jurisdictions in which changes in the fine levels were debated include Germany where on June 25, 2013 the Federal Cartel Office announced new guidelines for calculating fines that may lead to higher fines. Before closing, the Office of Fair Trading (OFT) in the United Kingdom, which was facing a 5% yearly budget reduction that may well have affected their ability to commit resources to costly investigations, increased the fine imposed on businesses in case of an infringement of competition law (OFT, 2013).

⁴ Cumulative Prospect Theory is a generalization of the standard Prospect Theory. Unlike in the standard Prospect Theory, in Cumulative Prospect Theory decision makers do not choose stochastically dominated option. For surveys of the theoretical literature on optimal law enforcement, see Garoupa (1997) and Polinsky and Shavell (2000).

example, argue against draconian sanctions as they may discourage marginal deterrence, may lead to inefficient overinvestment in private law enforcement, and may lead to bankruptcy, which is harmful to the society. Furthermore, current antitrust policy relies heavily on the use of self-reporting mechanisms (known as ‘leniency programs’) rather than industry audits for deterrence. But this had not been considered in the Beckerian model. Spagnolo (2004) shows that in contrast to Becker (1968) an optimally designed leniency program can achieve complete deterrence with a finite level of fine. The current study contributes to this debate by providing a clear result relating to the Beckerian Proposition question with a market experiment.⁵ The current study contributes also to the ongoing debate on optimal enforcement mechanisms, recently brought to the attention of the general public by *The Economist* (2012).

We consider an experimental market with inelastic demand and constant marginal cost in which three firms compete in a repeated Bertrand game (Dufwenberg and Gneezy, 2000). Firms can form a non-binding price cartel. However, such collusion is illegal and, if detected, can result in antitrust penalties. We vary the probability of detection and the level of the antitrust fine in a controlled manner such that the expected fine remains the same. More specifically, our analysis compares two treatments: one with a high ρ and a low F and a second with a low ρ and a high F that have the same expected cost of litigation $E(C) = \rho F$. We additionally include two treatments, aiming to reflect leniency programs (Motta and Polo, 2003), in which we allow subjects to self-report the existence of a cartel in return for a reduction in fines, but the expected cost to the non-reporting firms still remains the same.

The main finding of this study is that the Beckerian Proposition of the substitutability of fines and detection rates may be supported in an experimental framework. As predicted by the theory, different combinations of fine and detection rates with equal expected cost achieve the same deterrence effect. However, this is only true in an environment without leniency. With a leniency program, a high fine and low detection rate decrease the overall incidence of cartels, which is the ultimate aim of an anti-cartel mechanism. We explain this result with inconsistent beliefs about the detection probability when a leniency program is in effect. This paper, hence, provides supports from the point of view of behavioral economics (a la Chetty, 2015) for the policy move towards high fine when a leniency program is in effect. Finally, deviation from agreed

⁵ For the benefit of a behavioral economic analysis of law, see Jolls et al. (1998). Normann and Ricciuti (2009) and Hinloopen and Normann (2009) demonstrate how laboratory experiments can be used for economic policy making.

collusive price and reporting rates (under leniency) are independent of high or low fine combinations. The knowledge gained from this study is likely to guide both legal and economic discussions of rule enforcement, and can help to achieve a richer understanding of how economic agents may react to incentives under situations where violators are punished.

Previous research in non-market context has shown that the Beckerian Proposition may (e.g., De Angelo and Charness, 2012; Hoerisch and Strassmair, 2012) or may not (e.g., Friedland et al., 1978; Anderson and Stafford, 2003) be supported. Thus results of these studies cannot easily be transferred to the domain of antitrust infringement. A market framework differs from the frameworks employed in previous studies in at least two dimensions. First, whereas violating the law is an individual decision in areas such as tax evasion, speeding or stealing, it requires a coordinated action in a cartel setting. Second, no definite conclusion can be drawn from other experimental environments, as policy tools such as leniency are unique to this market setting. As a result, without specific tests no definitive forecast can be made about the validity of the Beckerian Proposition in a market context.

Table 1 places this study in the context of previous non-market experiments. The implications of the Beckerian Proposition to antitrust policy has widely been neglected in the experimental literature. To our knowledge, the only analysis is by Bigoni et al. (2015), who independently examine how leniency creates distrust among cartel members. They also vary detection rates and fines within a market frame – but use duopoly producers of differentiated goods and re-match the producers throughout the experiment. They find that absent leniency the probability of detection and expected fine are more effective to deter collusion, while with a leniency program fines deter collusion even when the probability of exogenous detection is zero. Since duopoly is a very specific case in which collusion is easier, and since in real life firms do not get re-matched every period, the conclusions regarding the general applicability of the Beckerian Proposition in an oligopoly market are mixed at the best.

The remainder of this chapter is structured as follows. Section 2 describes the details of the experiment. Results are provided in Section 3. Section 4 concludes the chapter.

Table 1: Related experiments.

Authors	Frame	Method	Finding
Friedland et al. (1978)	Tax evasion	Variation in either audit rate or fine with constant expected fine	Larger fines are a stronger deterrent than frequent audits (although this is not statistically significant)
Block and Gerety (1995)	Sealed-bid auction	Variation in either detection rate or fine, as well as offsetting change in both	Risk loving (averse) subject are more (less) responsive to a change in detection rate than in fines
Bar-Ilan and Sacerdote (2004)	Red-light running	Variation in either detection rate or fine with constant expected fine	Elasticity of violation with respect to increase in fines (detection) is between -.20 and -.30 (-.15 and -.22)
Anderson and Stafford (2003)	Free-riding on Public Goods	Variation in either detection rate or fine, both with increasing and constant expected fines	Marginal effect of an increase in fines is one third larger than of an increase in detection
De Angelo and Charness (2012)	Speeding	Uncertainty over the detection rate or fine. Subjects can vote for high (low) detection and low (high) fine regime	Preference for high fine and low detection regimes. No significant differences in speeding rates
Hoerisch and Strassmair (2012)	Stealing	Stealing & Variation in detection rate and fine, including treatments with same expected fine	No difference in deterrence for equal expected fines. Only high expected fines deter
Bigoni et al. (2015)	Duopoly Cartel	Variation in detection rate and fine, including treatments with leniency	With leniency, fines deter even with zero detection probability

2. The Experiment

2.1. Experimental procedure

The experiment was conducted at the Centre for Behavioural and Experimental Social Science at the University of East Anglia (UEA) in the Autumn of 2012. Subjects were 180 UEA students, without any prior experience in market experiments, recruited through the ‘Online Recruitment System for Economic Experiments’ or ORSEE (Greiner, 2015). We employed a fixed matching in which every subject was matched with the same other two subjects for at least 20 periods. This reflects the situation in real life where firms interact with each other in the same market repeatedly (and do not get rematched with other random firms in every period). To avoid end-game effects we implemented a random stopping rule: at the beginning of period 21 and of each of the following periods, there was a 20% chance that the experiment stopped.⁶

The experiment consisted of two parts. In the first part, subjects faced a pen-and-paper risk elicitation task (Holt and Laury, 2002) where subjects chose between a set of increasingly risky options or a safe payout.⁷ A computerized dice-throw determined the outcome, but subjects did not receive feedback about this part of the experiment until the end of the session. After completing the risk elicitation task, subjects were provided with both computerized and printed instructions (see Appendix B) for the second part of the experiment which was computerized using z-Tree (Fischbacher, 2007). A questionnaire was used to ensure understanding. Finally, after the experiment finished, subjects were asked to fill out a demographic survey.

For the first part, earnings were denoted in British pounds. For the second part, they were recorded in terms of ‘experimental points’, and converted to British pounds at a rate of 15p per point at the end of the experiment. The average payment was £11.41, including an initial endowment of £6 to cover potential losses. At the end of the experiment subjects were paid privately in cash. Sessions lasted between 45 and 60 minutes.

⁶ See Dal Bo (2005) for the importance of a random-stopping rule to reduce opportunistic behavior in strategic games.

⁷ We allowed subjects to show inconsistent risk preferences, which we control in the regression analysis. As a measure of risk preferences, we count the number of risky choices made. The more often a subject chose the risky option over the safe alternative, the more risk-loving he/she is.

2.2. Experimental Design

Our experimental design is a modified version of the cartel formation game in Gillet et al. (2011) and Hinloopen and Soetevent (2008). Subjects play the role of a firm with a common, constant marginal cost of 90. They face a repeated homogeneous-goods discrete Bertrand triopoly as in Dufwenberg and Gneezy (2000).⁸ In each period firms have to simultaneously decide if they want to form a non-binding cartel. If all three competitors in a given market decide to collude, they are informed that they mutually promised to charge the monopoly price. Firms then simultaneously select a price p from the discrete choice set $\{90, 91, \dots, 102\}$, but are not obliged to set their agreed-upon price. The firm charging the unique lowest price p^{min} , earns the full market profit $p^{min} - 90$, while firms with a higher price receive no earnings. In case of ties, firms split the profit equally.

In all but one treatment, reaching a price agreement comes at the risk of an antitrust fine, which is levied upon firms by a computerized Antitrust Authority. The novelty of our design comes from the controlled variation of the likelihood of detection and the magnitude of fines between the treatments. The detection probability can be either "low" (henceforth indicated by a small p) or "high" (hereafter indicated by a capital P). Likewise, fines can be either "low" (from now on indicated by a small f), or "high" (henceforth indicated by a capital F). Our design ensures that the expected cost (probability times fine level) is the same across the relevant treatments, i.e., $pF = Pf$. This allows us to experimentally distinguish the deterrent effect of fines and detection probabilities given the same expected fine cost, while the comparison to the baseline treatment with no fines or audits can reveal that firms are indeed sensitive to fine and detection probabilities. We chose the detection probability based on the estimation of cartel detection rates by Bryant and Eckard (1991), who report rates between 13%-17%. Several previous market experiments used a rate of 15% (Hinloopen and Soetevent, 2008; Gillet et al., 2012). We select 10% and 20% in order to ease the understanding for the subjects, while simultaneously selecting detection rates close to those observed in the real world.

Two further treatments allow firms to self-report the existence of a cartel in return for a reduction in fines. This makes it possible to explore the robustness of the Beckerian Proposition

⁸ We specifically avoided a duopoly framework, since it is a very special case and it is known that the behavioural issues of reputation, spite, reciprocity etc. are prominent in such a case and will dilute the main research question.

in the presence of the leniency policy that is unique to a cartel setting. Examining the validity of the Beckerian Proposition with and without leniency also allows us to give policy advice to countries, such as Indonesia or the Philippines, that have not (yet) introduced a leniency policy. Similar to Hinloopen and Soetevent (2008), reporting costs one experimental point. This is implemented in order to prevent firms to punish a deviating firm for free. If a firm is the sole self-reporter, it gains complete immunity from fines whereas the other firms have to pay the full fine. If two (three) firms report, their fine is reduced by half (one-third). Fines in these treatments with leniency are denoted with l and L , respectively. Table 2 summarizes the treatments.

Table 2: Experimental treatments

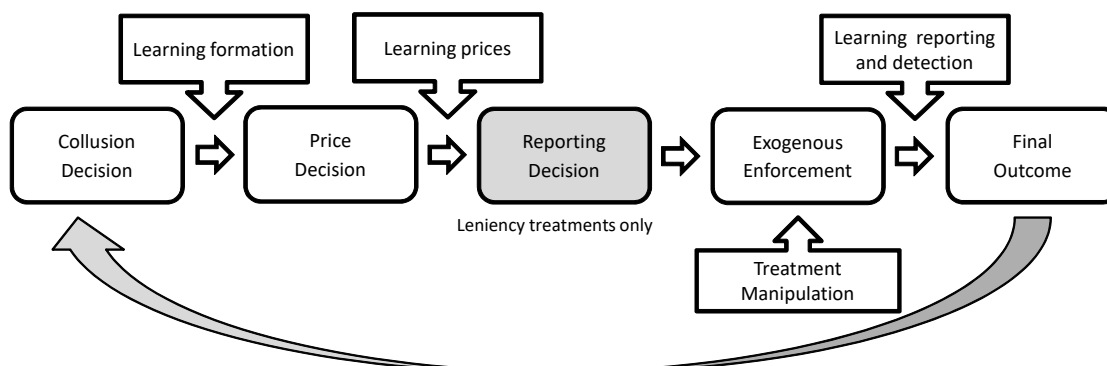
Probability	Fine	Without leniency	With leniency
10%	8	Low detection rate, high fine (Treatment pF)	Low detection rate, high fine (Treatment pL)
20%	4	High detection rate, low fine (Treatment Pf)	High detection rate, low fine (Treatment PL)
0%	0	Baseline	

Replicating real life, we assume that the liability for the illegal collusion lasts until the agreement has been detected or been revealed by means of a leniency application. This implies that a firm which stops colluding or deviates from its agreement can still be fined for its previous misconduct. At the beginning of each period of the experiment, firms are informed whether or not they are liable for a previous agreement. While firms can renew their agreement, they cannot end a potential previous liability. However, once fined, firms cannot be penalized again unless they decide to form a new cartel.

The timing and information structure of the game is summarized in Figure 1.

Figure 1:

Timing and information structure



1. Each firm expresses its willingness to reach an agreement over prices by selecting the appropriate button {yes, no}. If all firms in a given market wish to collude (click ‘yes’), they then enter a non-binding agreement to choose the joint profit maximizing price of 102. If at least one firm decides not to collude, then firms are informed about each rival’s choice and competition takes place in the market.
 2. Each firm chooses its price from the set {90, 91, ..., 102}. Firms then observe all prices in their market, and learn whether their price is the lowest submitted price.
 3. In the treatments with leniency, each firm can decide to reveal the existence of a cartel at the expense of one experimental point.
 4. If no firm self-reports, the cartel may still be detected by the Antitrust Authority with the detection probability specified in the treatment.
 5. In the last step, firms are informed about their earnings in this period, whether collusion was detected or not, and about the number, but not identity, of the whistleblowers (reporters).
- At the end of the experiment, the number of experimental points earned in each period minus the penalties paid is converted into cash. The earnings from the risk elicitation task and the Bertrand game are then summed up and paid out in private.

2.3. Theoretical Benchmark

Across all treatments there exist multiple equilibria, but all firms setting a price of 91 is the payoff dominant equilibrium, which is also our benchmark. A price of 91 yields a competitive

profit of $\pi^{comp} = \frac{p^{comp}-c}{n} = \frac{91-90}{3} = \frac{1}{3}$. However, firms can coordinate on prices above the competitive equilibria by choosing to collude. The joint profit maximizing price is 102, which yields per period collusive profits of $\pi^{coll} = \frac{p^{coll}-c}{n} = \frac{102-90}{3} = 4$. Engaging in price fixing comes at the risk of antitrust enforcement. Let ρ denote the probability that a fine is effectively imposed upon a colluding firm. Once a firm's engagement in an illegal cartel has been detected, the exogenous Antitrust Authority levies a one-time fine $\mathbb{F} = \begin{cases} f = 4 & \text{if } \rho = 20\% \\ F = 8 & \text{if } \rho = 10\% \end{cases}$ upon firms, where the "low" fine of 4 reflects a firm's one-shot profit from colluding, while a "high" fine of 8 equals twice the gain from colluding. It is important to note that the per-period expected fine $\rho\mathbb{F} = 0.8$ is constant across treatments. Firms are liable for their infringement for an infinite time period, but can only be fined once (unless they re-form a cartel following detection).

Denote δ as the rate of time preference. Then the net present value of the expected fine payments, given that if not punished the liability for fine rolls over to the future periods, is the expected fine in the first period of collusion. This equals the probability of detection (ρ) times the fine level (\mathbb{F}), plus the present value of the expected fine in the second period – which is the probability that the cartel was not detected in the first period ($1 - \rho$) times the probability of detection (ρ) times the fine level (\mathbb{F}) times the rate of time preference (δ), plus the present value of the expected fine in the third period, and so on. This equals $\rho\mathbb{F} + (1 - \rho)\delta\rho\mathbb{F} + (1 - \rho)^2\delta^2\rho\mathbb{F} + \dots = \frac{\rho\mathbb{F}}{1-\delta(1-\rho)}$. When collusion is enforced via grim-trigger strategies, a deviating firm slightly undercuts the collusive price, and gains a one shot deviation profit of $\pi^{dev} = p^{dev} - c = 101 - 90 = 11$, followed by reversion to the competitive equilibria. The incentive compatibility constraint (ICC) for the Baseline is then:

$$\frac{\pi^{coll}}{1-\delta} = \pi^{dev} + \delta \frac{\pi^{comp}}{1-\delta}, \Leftrightarrow \frac{\frac{p^{coll}-c}{n}}{1-\delta} = p^{dev} - c + \delta \frac{\frac{p^{comp}-c}{n}}{1-\delta}, \Leftrightarrow \frac{4}{1-\delta} = 11 + \delta \frac{\frac{1}{3}}{1-\delta}. \quad (1)$$

where the left-hand side (LHS) of equation (1) consists of the net collusive profit of continuous cartel infringement. The right-hand side (RHS) is the one-shot profit from deviation plus the expected earnings from reverting to competition.

Similarly, the ICC for a treatment absent leniency but with antitrust enforcement is given by:

$$\begin{aligned} \frac{\pi^{coll}}{1-\delta} - \frac{\rho\mathbb{F}}{1-\delta(1-\rho)} &= \pi^{dev} - \frac{\rho\mathbb{F}}{1-\delta(1-\rho)} + \delta \frac{\pi^{comp}}{1-\delta}, \Leftrightarrow \frac{\frac{p^{coll-c}}{n}}{1-\delta} - \frac{\rho\mathbb{F}}{1-\delta(1-\rho)} = p^{dev} - c - \frac{\rho\mathbb{F}}{1-\delta(1-\rho)} + \\ \delta \frac{\frac{p^{comp-c}}{n}}{1-\delta}, &\Leftrightarrow \frac{4}{1-\delta} - \frac{\rho\mathbb{F}}{1-\delta(1-\rho)} = 11 - \frac{\rho\mathbb{F}}{1-\delta(1-\rho)} + \delta \frac{\frac{1}{3}}{1-\delta}. \end{aligned} \quad (2)$$

where the LHS of equation (2) consists of the infinite gain from collusion minus the expected fine payment, and the RHS is the one-shot profit from deviation plus the expected earnings from competition, minus the expected fine payment. Note that the critical threshold for the discount factor in (1) and (2) is identical. As in the framework of Becker (1968), the theoretical prediction would therefore not report any significant differences between the treatments pF and Pf . Furthermore, note that in the presence of leniency, the optimal deviation strategy is to report at the expense of $c^{reporting} = 1$. The ICC for a treatment with leniency is then:

$$\begin{aligned} \frac{\pi^{coll}}{1-\delta} - \frac{\rho\mathbb{F}}{1-\delta(1-\rho)} &= \pi^{dev} - 1 + \delta \frac{\pi^{comp}}{1-\delta}, \Leftrightarrow \frac{\frac{p^{coll-c}}{n}}{1-\delta} - \frac{\rho\mathbb{F}}{1-\delta(1-\rho)} = p^{dev} - c - 1 + \delta \frac{\frac{p^{comp-c}}{n}}{1-\delta}, \\ \Leftrightarrow \frac{4}{1-\delta} - \frac{\rho\mathbb{F}}{1-\delta(1-\rho)} &= 10 + \delta \frac{\frac{1}{3}}{1-\delta}. \end{aligned} \quad (3)$$

The LHS consists of the net gain from collusion, while the RHS consists of the one-shot profit of deviation and reversion to competition, minus the cost of a leniency application but no expected fine payment exists due to the leniency towards the self-reporting firm.

2.4. Hypotheses

Insights from the law and economics literature, existing experimental findings and the theoretical benchmark offer predictions that we can examine within our experiment. The analysis will focus mainly on three statistics. First, we seek to investigate cartel formation, which can be measured by observing the actual incidence of collusive markets. The Beckerian Proposition implies that the severity and probability of punishment are substitutable (Becker, 1968). In our experimental setting this means that firms respond in the same way to an increase in the likelihood of an enforcement action as to an increase in the severity of antitrust fines when the expected fine is the same. The alternative hypothesis is that higher fines have a larger deterrence effect

(Anderson and Stafford, 2003), both with and without a leniency policy in place. Regarding cartels, the hypotheses (irrespective of leniency) are thus the following:

Hypothesis 1: When $\partial E(C)/\partial \rho = \partial E(C)/\partial \mathbb{F}$, firm response in cartel formation is expected to be the same for a marginal increase in ρ and a marginal increase in \mathbb{F} .

Alternative Hypothesis 1: When $\partial E(C)/\partial \rho = \partial E(C)/\partial \mathbb{F}$, firms are expected to be less likely to form a cartel for a marginal increase in \mathbb{F} than for a marginal increase in ρ .

When we consider leniency, however, it may be possible that the subject's belief about the detection probability is different from the stated exogenous one in the experiment. Since leniency involves a risk that a partner in crime might report the crime, the belief about the detection probability is higher. That is, subjects may make mistakes when forming subjective probabilities about detection, as indicated in the behavioral economics literature. In such a case the results with and without leniency might be different. We return to this issue later.

Second, we consider the impact on prices. An *Asking price* is the price a firm charges, whereas the *Market price* is the minimum price charged in a market. In the theoretical benchmark, the parameters of the enforcement regime do not influence the profit-maximizing price. Our null hypothesis is therefore that neither of the prices differ between the treatments. Stigler (1970) argues that tougher punishment may lead to a more severe crime. In a market framework, a more severe punishment may cause firms to charge higher prices (Jensen et al., 2013). Our alternative hypothesis is therefore that prices are higher when fines are large. Regarding pricing the hypotheses are thus:

Hypothesis 2: When $pF = Pf$ then the asking price as well as the market price do not vary across probability-fine combinations (i.e., $\text{price}_{pF} = \text{price}_{pF}$ and $\text{price}_{pL} = \text{price}_{pL}$).

Alternative Hypothesis 2: When $pF = Pf$ then the asking price as well as the market price are higher in F (L) compared to f (l) (i.e., $\text{price}_{pF} > \text{price}_{pF}$ and $\text{price}_{pL} > \text{price}_{pL}$).

Finally, we investigate cartel stability by observing how often firms within a cartel deviate from the joint profit-maximization price, and how often they self-report in the case of leniency. As incentive constraints in our setting are satisfied for all treatments, a colluding firm should stick to

a collusive agreement and should not apply unilaterally for leniency, independent of the detection rate and the fine level. Our null hypotheses therefore states that there will be no difference in cartel stability (in terms of deviation or in terms of reporting) between the treatments. We test this against the alternative hypothesis that there will be more self-reporting and deviations in pL than in Pl . We expect this, because due to behavioral bias, deviating firms will try to avoid high fines by self-reporting. In summary, we state the following null hypotheses which we test against the alternative hypotheses:

Hypothesis 3A: When $pL = Pl$ then the number of deviations from the agreed price are the same across probability-fine combinations (i.e., number of deviations $_{pL}$ = number of deviations $_{Pl}$).

Alternative Hypothesis 3A: When $pL = Pl$ then there will be more deviations in pL than in Pl (i.e., number of deviations $_{pL} >$ number of deviations $_{Pl}$).

Hypothesis 3B: When $pL = Pl$ then the number of self-reports are the same across probability-fine combinations (i.e., number of reports $_{pL}$ = number of reports $_{Pl}$).

Alternative Hypothesis 3B: When $pL = Pl$ then there will be more self-reporting in pL than in Pl (i.e., number of reports $_{pL} >$ number of reports $_{Pl}$).

3. Results

The results are presented in three parts. First, we test whether combinations of detection rate and level of fines resulting in equal expected fines are equally successful in deterring collusion, or whether any particular policy regime is more successful in reducing the actual incidence of cartels (Hypothesis 1). Next, we compare the prices (and hence consumer welfare) under each antitrust regime. We ask if higher fines and lower detection probabilities diminish collusive price (Hypothesis 2). Finally, we focus on successfully formed cartels and investigate defection and self-reporting (Hypotheses 3A and 3B).

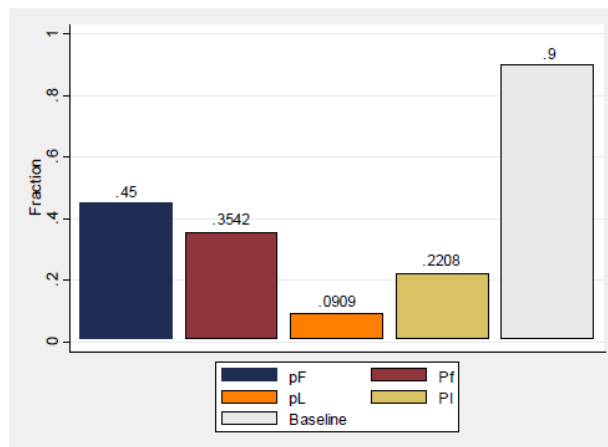
Throughout the paper all tests are performed with the entire sample, but restricting the analysis to observations from round 1 to 20 produces a consistent sample that we report when relevant. Since the observations are inter-dependent within a market, the average statistic of all three firms combined constitutes one unit of observation. Thirty-six subjects participated in each

treatment and we have 59 independent observations.⁹ We further carry out a panel data analysis reported in the relevant subsections.

3.1. Cartel Activity

Our key indicator to test the Beckerian Proposition is the rate of cartelized markets – the percentage of markets in which a cartel exists, taking into account that undetected cartels carry over into later periods. We define a market to be cartelized if a cartel agreement was in place at the price decision stage. Figure 2 shows the average fraction of cartelized markets aggregated over all periods, and highlights the relative effectiveness of each treatment in reducing the occurrence of cartels as compared to a laissez-faire baseline.

Figure 2. Average fraction of cartelized markets.



As can be observed, antitrust regimes differ greatly in the resulting number of cartelized markets. With antitrust enforcement, between 9% and 45% of all markets are cartelized, while in a laissez-faire environment 90% markets are cartelized. At a first glance, the rate varies along two dimensions. There seem to be a difference between low fine - high detection and high fine - low detection regimes, and there seems to be fewer cartels with than without leniency. We check both the phenomenon one by one.

⁹ One observation had to be dropped, as two subjects accumulated fines that were greater than their profit plus initial endowment. Treatment *pL* hence has 11 independent observations.

While our results indicate fewer cartels for high detection rates - low fines absent leniency, the opposite pattern emerges with leniency. The difference in the percentage of cartelized markets across all treatments (except baseline) is statistically significant (Kruskal-Wallis test, $p=0.04$). We compare pF vs. Pf and pL vs. Pl in order to test for the substitutability of detection rate and sanctions with and without leniency. We find support for Becker (1968), as we cannot reject our null hypothesis of equal population means for low detection rates and high fines without leniency (Mann-Whitney test, $p=0.56$). However, a higher fine and lower detection regime reduces the number of cartelized markets in the presence of leniency (one-sided t-test, $p=0.04$) questioning the general validity of the Beckerian Proposition. An analysis of the evolution of cartelized markets over time reveals that the least number of cartels were operating in the pL treatment, followed by Pl and then the two treatments without leniency.

An alternative indicator of cartel activity commonly used in the literature (Hinloopen and Soetevent, 2008; Gillet et al., 2011; Bigoni et al., 2012) is the propensity to collude, i.e., the percentage of firms in favor of cartel formation. Table 3 contains the descriptive statistics for this alternative statistic.

Table 3: Propensity to collude – Average (Std. Dev.) per treatment.

Probability	Fine	Without leniency	With leniency
10%	8	50.74 (19.04)	53.84 (10.42)
20%	4	49.74 (16.97)	64.67 (12.33)
Baseline		76.69 (12.33)	

Note: The propensity to collude is calculated using the binary decision of a firm to attempt a collusion.

Not surprisingly, we note that in comparison with the baseline treatment, all antitrust sanctions effectively deter collusion attempts. Of greater interest, however, is that the difference in the propensity to collude across treatments in which an enforcement regime is in place is statistically significant (Kruskal-Wallis test, $p<0.01$).¹⁰

¹⁰ We also investigated the attempt to collude at the very first period of the experiment, which can be seen as a measure of pre-deterrence. There is no significant difference between the enforcement regimes.

In order to understand what drives the differences, we focus on the leniency policy. A comparison reveals that the propensity to collude is about 9% higher in the presence of a leniency program, and this is statistically significant (Mann-Whitney test, $p=0.04$). This hints at the possible pro-collusive effect of leniency, described in Motta and Polo (2003) and Spagnolo (2000), according to which firms use self-reporting as a punishment against defectors. Next, we turn to a comparison of pF vs. pL and Pf vs. Pl , in order to test if the pro-collusive effect exists for both detection-fine ratios. A bivariate test yields no significant differences between the two treatments with a low detection rate and high fines, but collusion attempts are significantly more frequent in the Pl than in the Pf treatment (Mann-Whitney test, $p=0.03$).

Our subsequent focus is on the second potential driver, i.e., the difference between the detection rates and fines. We pool pF and pL and compare them with pooled Pf and Pl and cannot find any statistically significant difference (Mann-Whitney test, $p>0.1$). However, as we showed that treatments with and without leniency differ in their respective deterrence, we need to assess the substitutability of fine and detection rates for each policy regime separately. Table 4 documents the p-values of pairwise two-sided Mann-Whitney comparisons.

Table 4: Propensity to collude – p-values of pairwise two-sided MWU-tests.

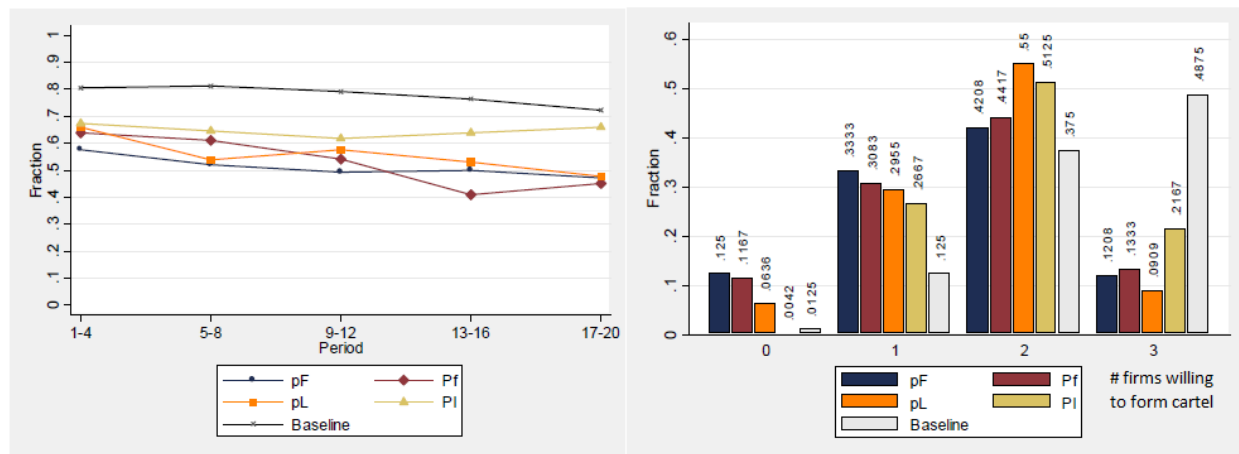
	pF	Pf	pL	Pl
Baseline	0.0039***	0.0016***	0.0081***	0.0325**
pF		1.0000	0.6225	0.0646*
Pf			0.7583	0.0282**
pL				0.0488**

Note: * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

The table can be read in the following way. First, there is no significant difference between the treatments without leniency (note that $p = 1$ are approximations). This is particularly interesting, as it supports the substitutability of fine and detection rates to achieve the same deterrence. However, the table also reveals that the difference in the propensity to collude between

pL and Pl is statistically significant (Mann-Whitney test, $p < 0.05$). This finding questions the robustness of the Beckerian Proposition when a leniency policy is in place.

Figure 3: Evolution of the fraction of firms who wish to form a cartel (Left) and histogram of the number of firms willing to form a cartel (Right).



To attain a more concrete understanding of a firm's decision to favor collusion, we now consider the evolution of the propensity to collude over time. We use the restricted sample of 20 rounds to display dynamics over time in order to avoid possible distortions caused by the unbalanced number of observations in later rounds. The dynamics of the fraction of firms that favor collusion are tracked on the left hand side of Figure 3, in which we have divided the time dimension into four periods. The right hand side of Figure 3 depicts a histogram of the number of firms in a market that were willing to collude. For the former, note that collusion rates tend to decline mildly over time, with the exception of Pl which slightly converges towards the Baseline. For the latter, note that cartel formation is a unanimous decision: a cartel is only formed if all three firms express their willingness to collude. We observe that treatments with leniency have the highest number of "all-but-one" cases, which is in line with the findings by Hinloopen and Soetevent (2008). Most importantly, the right hand side of the histogram depicts the rate at which cartels are being formed (i.e., all three firms agreed to collude, regardless of the existence of a cartel in previous periods). A pairwise comparison of the rate at which cartels are being formed reveals no statistically significant difference between pF and Pf , but the observed higher rate in Pl than in pL is statistically significant (one-sided t-test, $p = 0.05$). Note that the lowest rate of cartel

formation is in the *pL* treatment, indicating that in the presence of leniency, high fines and low detection rates seem most effective in deterring cartels.

The analysis so far, however, is not complete as we aggregated the individual decisions in each market and hence did not fully explain the causes of this result at the firm-level. In the next step of our analysis, we therefore conduct a regression analysis in which we treat each firm as a unit of observation in order to better understand the behavioral forces that drive our initial findings. The model explains a firm's individual decision to engage in a cartel by means of a dynamic random-intercepts logit model where the dependent variable is the binary choice to attempt collusion. To account for potential random disturbances caused by the group composition, we employ random-effect at the level of markets. In addition to the treatment dummies, we include a period and a period-squared variable to correct for a potential trend over time. Independent variables further include the lagged decision to collude in the previous period (*Decision to collude_{t-1}*), a dummy indicating whether or not a cartel has been successfully formed in the previous period (*Cartel formed_{t-1}*) and a dummy indicating whether a cartel has been detected (*Cartel detected_{t-1}*) or reported (*Cartel reported_{t-1}*) in the previous period. Further, we use a dummy which takes the value 1 if a cartel existed in the previous period and at least one member deviated by charging a price below the collusive one. In a further set of estimations, we add additional variables. In model 2, we control for individual risk preferences by including the number of risky choices that were made during the risk elicitation task, as well as a dummy variable (inconsistent preferences) to control for subjects that expressed inconsistent risk attitudes by switching more than once between the safe and the risky lottery options.¹¹ Finally, in model 3 we use the number of times a firm has so far been involved in a cartel, as well as the number of times its engagement in a cartel was detected or reported, as alternative explanatory variables. Table 5 displays the results of the regressions.

¹¹ Controlling for socio-demographic characteristics such as age, gender and nationality does not affect the sign or significance of the estimated coefficients.

Table 5: Decision to collude – Random effects logistic regression

Decision to collude	<u>Without leniency (Base: pF)</u>			<u>With leniency (Base: pL)</u>		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Pf	0.0411 (0.250)	0.165 (0.271)	0.236 (0.231)			
Pl				0.381** (0.170)	0.376** (0.169)	0.314** (0.146)
Decision to collude _(t-1)	2.933*** (0.139)	2.766*** (0.142)	2.582*** (0.132)	3.571*** (0.163)	3.563*** (0.163)	3.179*** (0.142)
Period	-0.00630 (0.0390)	-0.00995 (0.0394)	0.0321 (0.0412)	-0.0166 (0.0446)	-0.0182 (0.0446)	0.0129 (0.0449)
Period²	-0.000646 (0.00140)	-0.000591 (0.00141)	-0.00115 (0.00141)	-0.000307 (0.00164)	-0.000249 (0.00165)	-0.000566 (0.00161)
Cartel formed _(t-1)	-0.764*** (0.220)	-0.640*** (0.233)		0.648 (0.580)	0.859 (0.595)	
Cartel detected _(t-1)	-0.625** (0.288)	0.617** (0.303)		-0.298 (0.480)	-0.425 (0.487)	
Cartel reported _(t-1)				-2.278*** (0.583)	-1.674** (0.686)	
Price defection _(t-1)	-0.0355 (0.174)	-0.087 (0.181)		-0.908 (0.583)	-0.891 (0.586)	
Risk choice		0.159*** (0.027)	0.168*** (0.027)		0.0321 (0.029)	0.0248 (0.027)
Inconsistent preference		-0.251 (0.241)	-0.284 (0.242)		-0.209 (0.205)	-0.094 (0.185)
# times busted			-0.257 (0.163)			0.409*** (0.151)
# times colluded			-0.0216 (0.0228)			0.320** (0.129)
Constant	-1.216*** (0.302)	-1.898*** (0.335)	-2.153*** (0.334)	-1.309*** (0.288)	-1.386*** (0.309)	-1.609*** (0.299)
Observations	1710	1710	1710	1524	1524	1524

Note: Standard errors in parentheses; * p<0.10, ** p<0.05, *** p<0.01

For the regressions in the three columns on the left-hand side, the pF treatment is used as a benchmark, represented by the constant term. On the right-hand side, we use the pL treatment as our benchmark in order to investigate the effect of a different detection-fine regime given the presence of a leniency program. The regressions confirm the earlier results from the non-parametric analysis. The coefficient of the treatment dummy Pf is not statistically significant, indicating no difference in deterrence, while the estimated coefficient Pl is of positive sign and significant at the 5% level.

With respect to the other variables, we make the following observations. First, there is strong evidence of behavioral momentum, i.e., the previous period's decision to collude, represented by the `Decision to colludet-1` dummy, positively affects the decision in the current period. Second, we do not obtain a statistically significant effect of time between the treatments, and whether or not a price deviation occurred in the previous period also seems irrelevant. Third, as undetected cartels carry over into the next periods, without leniency forming a cartel in the previous period negatively affects the odds to decide to collude. Interestingly, experiencing an antitrust action has a deterrence effect by reducing the odds to collude. However, `Cartel formedt-1` and `Cartel detectedt-1` are not significant in the regressions with leniency. This is because these effects are incorporated in the likelihood of being reported by a partner in crime. The size and sign of the coefficient `Cartel reportedt-1` indicate that experiencing self-reporting is one of the main factors that deters a firm's decision to collude again. Fourth, the inconsistent risk preferences variable is not significant. It is probably because subjects with inconsistent preferences would have varying behavior and therefore insignificant coefficients. Finally, while controlling for risk preferences does not change the sign or statistical significance of the coefficients, risk choice turns out significant in the comparison of the treatments without leniency, but not in the comparison with leniency. This, again, is because due to leniency the risk of getting caught is higher and this is incorporated in the `Cartel reportedt-1` variable.

Combining the non-parametric test results as well as the results from the regressions, we can now present our first main result:

Result 1: Cartelized Markets

Absent leniency, the fine and detection rate are substitutes with respect to the occurrence of cartels – supporting the Beckerian proposition. However, when leniency exists, a lower detection

probability and higher fine regime is significantly stronger in reducing the number of active cartels than a higher detection and lower fine regime.

The result partially (in absence of leniency) supports the Beckerian proposition. But it does not directly shed light on why the anomaly is observed when leniency is in practice. The regression offers a possible behavioral explanation for this finding. It is possible that the perceived probability of detection is distorted under leniency. As a result of such probability distortion (in the line of Tversky and Kahneman, 1992) subjects perceive the detection rate under leniency much higher and give high weight to the lag report variable. This implies a perceived high expected cost under the high fine regime, resulting in reduction in cartel formation.

3.2. Market Prices

Although understanding the determinants of collusion is useful, a more important analysis relates to the market price. A change in the level of fines and detection rates might also affect the price that colluding firms charge. An antitrust authority that cares about consumer welfare will try to achieve lower prices while changing the enforcement regime, or at least it will try to prevent an increase in prices. How an incorrectly designed enforcement regime can provide incentives to commit a more severe crime was first discussed by Stigler (1970) and has recently been explored by Jensen et al. (2013) for collusion. Their models predict that firms might react to higher fines by increasing their prices. Here we investigate the effects of antitrust policy on prices.¹²

Table 6 shows the market prices for all treatments, differentiated between the price charged in rounds with and without a cartel. We make the following two observations. First, market prices in the collusive markets are about 3.5% above the prices in the competitive markets. This supports the gain from collusion that we identified previously. Second, different enforcement regimes have essentially no effect on market prices in competitive markets. Prices absent collusion are close to the theoretical Bertrand equilibrium. Furthermore, the prices in collusive markets are about 7.2% below the joint profit maximizing price which indicates the existence of price deviations.

¹² Another useful way is to investigate this issue is to analyse the effects on asking prices (average of the three stated price). We discuss this in Appendix A. The results are not very different.

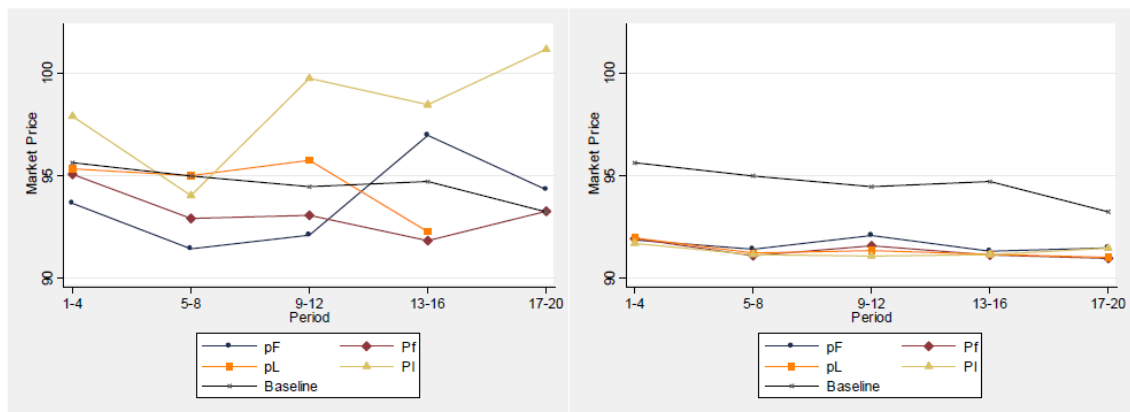
Table 6: Market prices – Average (Std. Dev.) per treatment.

Probability	Fine	<u>Collusive</u>		<u>Competitive</u>	
		Without leniency	With leniency	Without leniency	With leniency
10%	8	93.82 (3.25)	94.61 (3.11)	91.56 (0.90)	91.33 (1.20)
20%	4	93.04 (1.99)	95.47 (4.37)	91.20 (0.32)	91.29 (0.68)
Baseline		94.32 (2.68)		93.62 (1.25)	

Note: Market prices are calculated as the minimum of the three stated prices in a market.

In a further Kruskal-Wallis test we find that prices in cartel groups may appear more dispersed than in competitive markets, but there is no statistically significant difference between them with or without leniency ($p > 0.1$).¹³ A pairwise comparison using Mann-Whitney tests in a similar manner as in our previous analysis confirms this. In other words, we observe no statistically significant evidence that suggests any validation of the claim that policy regimes will influence the severity of the committed crime. These regularities become easily recognizable in Figure 4, which reports the evolution of market prices over time, both for the collusive and the competitive markets.

Figure 4. Market prices for collusive (Left) and competitive (Right) markets.



¹³ This holds also for a comparison of market prices without distinguishing between collusive and competitive markets.

The observed patterns over time do not allow us to reject Hypothesis 2. We can thus present our second result:

Result 2: Prices

With a constant expected fine, irrespective of the presence of a leniency program, the market prices remain the same across treatments.

To assess which policy regime is to be favored from a consumer's point of view, we further investigate the average consumer welfare, which is defined as the difference between the maximum willingness to pay of 102 and the actual market price. It is not immediately clear whether or not a leniency program is welfare improving (Kruskal-Wallis test, $p > 0.1$). In pairwise comparison of pF and Pf to pL and Pl , we find no significant difference. Hence, ceteris paribus, if a higher level of investigation requires a higher level of logistic expenditures, then given the same consumer surplus, a high fine regime may be preferred.

3.3. Cartel Stability

In the final part of the analysis we focus on successfully formed cartels in order to understand cartel stability. Specifically, we investigate defection and self-reporting, which can be understood as a proxy for the internal (in)stability of a cartel. We measure defection by the percentage of firms within a cartel that select a price below 102 and hence deviate from the agreement. Table 7 provides the average defection rates for each treatment.

Table 7: Rate of price defection (in %) – Average (Std. Dev.) per treatment.

Probability	Fine	Without leniency	With leniency
10%	8	69.84 (27.70)	57.14 (18.35)
20%	4	74.54 (20.92)	53.78 (31.05)
Baseline		66.97 (23.83)	

Note: The average rate of price defection (conditional upon the existence of a cartel) is the percent of firms that deviated from the agreed cartel price. It is calculated using a dummy that takes the value of 1 if a cartel member stated a price less than 102, and 0 otherwise.

Note that defection rates vary significantly across treatments at the 10 percent significance level (Kruskal-Wallis test, $p=0.09$). Firms undercut the agreed upon price more rigorously in the absence of leniency. In fact, the rate of price deviations is about 17% lower for the two leniency treatments, and this difference is statistically significant (Mann-Whitney test, $p=0.02$). This finding is not surprising, as it has been often argued that firms utilize the leniency program to punish deviators. E.g. Hinloopen and Soetevent (2008) report that the agreed-upon price is undercut in 97% of the cases with leniency as compared to 75% without leniency.

Of greater interest is the difference between pF and Pf , and between pL and Pl , which are both statistically insignificant (Mann-Whitney test, $p > 0.1$). However, it is important to note that only about 9% of all markets in the pL treatment had a cartel. The number of observations that we can use for statistical tests is hence limited, so that we may lack the power necessary to find significant differences.

Table 8: Rate of reporting in leniency (in %) – Average (Std. Dev.) per treatment.

Probability	Fine	Reporting	Given own deviation	Given other firm deviation
10%	8	54.34 (11.55)	34.12 (09.31)	53.17 (11.50)
20%	4	56.52 (30.10)	37.71 (26.66)	54.35 (32.26)

Note: The average rate of reporting (calculated only for the Leniency treatments) is the percent of firms, as cartel members, that report a cartel. It is calculated using a dummy that takes value 1 if a cartel member self-reports, and 0 otherwise.

We now focus on the use of the leniency program by self-reporting, i.e., when a firm reveals the existence of a cartel to avoid the possibility of an antitrust fine. Recall, however, that self-reporting does not guarantee full immunity from fines. Similar to the design of leniency programs in the experimental literature, a reporting firm may still pay a (reduced) fine if more than one firm reports the cartel. Table 8 contains the average reporting rates for each treatment.¹⁴ The rate of

¹⁴ An alternative way to analyze the effect of leniency is to observe the fraction of established cartels that collapse due to reporting. In the pL treatment, 95.23% of the established cartels had at least one whistleblower, compared to 82.88% in Pl . While on a first view these rates appear extremely high, they are not too different from the 78% reported in Hinloopen and Soetevent (2008).

self-reporting using all observations is reported on the left side, while the right side of Table 8 provides with the rate of self-reporting using only observations where a firm either deviated itself, or experienced a deviation from another cartel member.

We observe no statistically significant difference between the two treatments with leniency (Mann-Whitney test, $p > 0.1$). While this does not allow us to reject the our null hypothesis 3B in support of the alternative hypotheses, we need to be aware that very few markets in ***pL*** are cartelized and that this limits the number of observations from which we can draw conclusions.

To investigate if firms use the leniency program as part of a deviation strategy, we test for the percentage of cartel members that self-report after they have deviated from the collusive price. This strategy is used by 34.12% and 37.71% of firms in ***pL*** and ***Pl***. Next, we check if firms self-report to punish deviators. Indeed 53.17% (54.35%) of firms in ***pL*** (***Pl***) report after deviations by others (conditional on sticking to the collusive agreement themselves). This pattern indicates that firms use leniency more often to punish deviators, than as part of their own deviation strategy. However, as the differences are not statistically significant, we conclude:

Result 3: Stability

Firms deviate less often in the presence of leniency, and report more often if fines are low and detection is more likely. However, the deviation rate as well as the reporting rate do not vary significantly between different detection-fine combinations.

4. Conclusion

We experimentally examine the Beckerian Proposition, according to which different combinations of the magnitude and the likelihood of punishment achieve the same deterrence effect, in a market setting. This key principle in the law and economics literature has been supported in previous laboratory experiments on speeding and stealing but not in other experimental settings such as free-riding and tax evasion. The ambiguous evidence makes it difficult to draw conclusions for the design of optimal law enforcement mechanisms by antitrust authorities who face a trade-off between economizing on costly enforcement actions and the potential adverse effects of a higher fine rate. Criminal activities in a market framework differ from all previously studied situations, as the violation of antitrust laws is a coordinated rather than an individual action. Moreover, antitrust agencies utilize policy tools such as leniency to weaken

incentives and punish wrongdoers. It is therefore unclear how firms will react if authorities vary either the likelihood of detection or the level of fines but keep the expected fine constant. The current study closes this gap by experimentally varying the probability of detection and the amount of antitrust fines in a repeated Bertrand game with inelastic demand and exogenous antitrust enforcement.

In summary, we find support for the Beckerian Proposition, but only when there is no leniency policy in place. With a leniency policy, fines and the probability of detection are not perfect substitutes. In specific, we find that without leniency, fines and detection rates are substitutes. It is reassuring that, as predicted by theory, different combinations of the magnitude and the likelihood of punishment seem to be interchangeable instruments to deter cartels. However, when a leniency policy exists, a lower detection rate with higher fines significantly reduces the rate at which firms attempt to form a cartel. More importantly, a high fine and low detection policy under leniency decreases the overall incidence of cartels, which is the ultimate aim of a deterrence mechanism. We find the effects of different detection-fine combinations on market prices and observe that no fine-detection regime is significantly superior in terms of its destabilization of cartels. These results are consistent with the presence of behavioral bias among test subjects. If this bias is present among real cartel participants, then high fines would be more effective at reducing cartel activity than high rates of detection, *ceteris paribus*.

From a policy point of view, the results have important implications. The results indicate that society cannot just economize on costs of enforcement, as postulated by Becker (1968), when a leniency policy is in place or under consideration as a policy tool. The results give empirical support for the policy move towards higher fines as orchestrated recently by the erstwhile Office of Fair Trading in the UK or the ones debated in Germany and the US.

An important caveat needs to be stated as we discuss the policy implications. In our experiment students played the roles of the firms. Hence, if there are differences in behavior between firm managers and students, the final results may be affected. For example, unlike student behavior, firm behavior might be unaffected by the leniency policy. Hence, although the literature shows that professional and student behavior do not diverge significantly (Frechette, 2015) and that experimental results can indeed be applied for competition policy (Hinloopen and Normann, 2009), one needs to be careful about the implementation of our results in the field.

The results raise two immediate questions: First, why does the Beckerian Proposition hold absent leniency, but not when a leniency policy exists? And second, if the detection rate and fine are not substitutable, why do we observe stronger deterrence in pL than in Pl ?

A simple behavioral theory of probability distortion (*a la* Tversky and Kahneman, 1992) can answer both the questions. Firms may assume a different perceived likelihood of detection when a leniency program exists. Absent leniency, the perceived detection probability is the exogenously given probability – and hence no significant difference between pF and Pf exists. However, the perceived detection probability with leniency is a combination of the exogenous detection rate and the belief that other firms may self-report (say, τ). The aggregated perceived probability is then $(\tau + p)$ in pL and $(\tau + P)$ in Pl . It is easy to observe that the perceived expected cost in such a case is higher in pL than in Pl . Hence, the Beckerian Proposition may break down under leniency, especially if the belief that other firms may self-report is very high. It is, however, also possible to explain our results even when τ is not too high. The perceived likelihood that another firm self-reports may also depend on the fine levels, as a higher (lower) fine provides more (less) incentives to self-report following a non-linear probability weighting (Tversky and Kahneman, 1992; Dhami and al-Nowaihi, 2013). If for pL the perceived likelihood of detection is greater than for Pl , this results in higher expected cost in the pL treatment. A support for this explanation comes from the regression results in Table 5 that shows significance for the lag report variable and lack of significance for risk preference under leniency.

There are various interesting directions to extend the current study. Issues such as wastefully spending resources on avoidance activities (Chowdhury and Wandschneider, 2014), whether the Beckerian Proposition holds when the fine level is endogenous to cartel damage, and which of the fine or detection tools have bigger effects on post-cartel tacit collusion (Chowdhury and Crede, 2015) have not yet been investigated. We leave these for future research.

References

- Anderson, L.R. and S.L. Stafford (2003). 'Punishment in a Regulatory Setting: Experimental Evidence from the VCM', *Journal of Regulatory Economics*, **24**(1), 91-110.
- Angner, E., and G. Loewenstein (2007), 'Behavioral Economics', in Uskali Mäki, Dov M. Gabbay, Paul Thagard and John Woods (eds), *Philosophy of Economics*, Elsevier, pp. 641-689.
- Bailey, E.M. (2015), 'Behavioral Economics and U.S. Antitrust Policy,' *Review of Industrial Organization*, **47**(3), 355-366.
- Bar-Ilan, A. and B. Sacerdote (2004), 'Response of Criminals and Noncriminals to Fines', *Journal of Law and Economics*, **47**(1), 1-17.
- Becker, G. (1968), 'Crime and Punishment: An Economic Approach', *Journal of Political Economy*, **76**, 169-217.
- Bigoni, M., S. Fridolfsson, C. Le Coq, and G. Spagnolo (2012), 'Fines, Leniency and Rewards in Antitrust', *Rand Journal of Economics*, **43**(2), 1756-2171.
- Bigoni, M., S. Fridolfsson, C. Le Coq, and G. Spagnolo (2015), 'Trust, Leniency, and Deterrence', *Journal of Law, Economics, and Organization*, **31**(4), 663-689.
- Block, M.K. and V.E. Gerety (1995), 'Some Experimental Evidence on Differences between Student and Prisoner Reactions to Monetary Penalties and Risk', *Journal of Legal Studies*, **24**(1), 123-138.
- Block, M.K. and J.G. Sidak (1980), 'The cost of antitrust deterrence: Why not hang a price fixer now and then?', *Georgetown Law Journal*, **68**(5), 1131-1139.
- Bryant, P.G. and W. Eckard (1991), 'Price Fixing: The Probability of Getting Caught', *Review of Economics and Statistics*, **73**(3), 531-536.
- Camerer, C.F., and G. Loewenstein (2004), 'Behavioral Economics: Past, Present, Future', in Colin F. Camerer, George Loewenstein, and Matthew Rabin (eds), *Advances in Behavioral Economics*, Princeton University Press, pp. 3-51.
- Chetty, R. (2015), 'Behavioral Economics and Public Policy: A Pragmatic Perspective,' *American Economic Review*, **105**(5), 1-33.
- Chowdhury, S.M., and C. Crede (2015), 'Post-Cartel Tacit Collusion: Determinants, Consequences, and Prevention', University of East Anglia Centre for Competition Policy Working Paper, 15-1.
- Chowdhury, S.M., and F. Wandschneider (2014). 'An Experimental Analysis of Antitrust Enforcements under Avoidance', Paper presented at the First International Meeting on Experimental and Behavioural Social Sciences, University of Oxford, April 10.
- Competition and Market Authority (2014), 'Achieving a culture of compliance', speech delivered by CMA Chief Executive Alex Chisholm, 16 May.
- Dal Bo, P. (2005), 'Cooperation under the shadow of the future: experimental evidence from infinitely repeated games', *American Economic Review*, **95**, 1591-1604.

- DeAngelo, G. and G. Charness (2012), 'Deterrence, expected cost, uncertainty and voting: Experimental evidence', *Journal of Risk and Uncertainty*, **44**(1), 73-100.
- Dhami, S. and A. al-Nowaihi (2013), 'An extension of the Becker proposition to non-expected utility theory', *Mathematical Social Sciences*, **65**, 10-20.
- Dufwenberg, M. and U. Gneezy (2000), 'Price competition and market concentration: an experimental study', *International Journal of Industrial Organization*, **18**(1), 7-22.
- Ehrlich, I. (1973), 'Participation in illegitimate activities: a theoretical and empirical investigation', *Journal of Political Economy*, **81**(3), 521-565.
- Fischbacher, U. (2007), 'z-Tree: Zurich Toolbox for Ready-made Economic Experiments', *Experimental Economics*, **10**(2), 171-178.
- Fréchette, G.R. (2015), 'Laboratory experiments: Professionals versus students', in Guillaume Fréchette and Andrew Schotter (eds), *Handbook of experimental economic methodology*, Oxford University Press, USA, pp. 360-389.
- Friedland, N., S. Maital, and A. Rutenberg (1978), 'A simulation study of income tax evasion', *Journal of Public Economics*, **10**(1), 107-116.
- Garoupa, N. (1997), 'The Theory of Optimal Law Enforcement', *Journal of Economic Surveys*, **11**, 267-295.
- Gillet, J., A. Schram, and J. Sonnemans (2011), 'Cartel formation and pricing: The effect of managerial decision-making rules', *International Journal of Industrial Organization*, **29**, 126-133.
- Greiner, B. (2015), 'Subject pool recruitment procedures: organizing experiments with ORSEE', *Journal of the Economic Science Association*, **1**(1), 114-125.
- Hinloopen, J. and A.R. Soetevent (2008), 'Laboratory evidence on the effectiveness of corporate leniency programs', *Rand Journal of Economics*, **39**(2), 607-616.
- Hinloopen, J., and H. Normann, (eds) (2009). *Experiments and competition policy*, Cambridge University Press, USA.
- Hinloopen, J., and H. Normann (2009), 'Experimental economics and the practice of competition policy enforcement' in Jeroen Hinloopen, and Hans-Theo Normann (eds), *Experiments and competition policy*, Cambridge University Press, USA, pp. 301-311.
- Hoerisch, H. and C. Strassmair (2012), 'An experimental test of the deterrence hypothesis', *Journal of Law, Economics, & Organization*, **28**(3), 447-459.
- Holt, C.A., and S.K. Laury (2002), 'Risk Aversion and Incentive Effects', *American Economic Review*, **92**(5), 1644-1655.
- Jensen, S., O. Kvaloy, T.E. Olsen, and L. Soergard (2013), 'When tougher punishment leads to a more severe crime: an application to antitrust enforcement", NHH Dept. of Economics Discussion Paper No. 04.
- Jolls, C., C.R. Sunstein, and R. Thaler (1998), 'A behavioral approach to law and economics', *Stanford Law Review*, **50**, 1471-1550.

- Kahneman, D. and A. Tversky (1975), 'Judgement Under Uncertainty: Biases and Heuristics', in Dirk Wendt and Charles Vlek (eds), *Utility, Probability, and Human Decision Making*, Springer, pp. 141-162.
- Kolm, S. (1973), 'A Note on Optimum Tax Evasion', *Journal of Public Economics*, **2**, 265-270.
- Korobkin, R.B. and T.S. Ulen (2000), 'Law and Behavioral Science: Removing the Rationality Assumption from Law and Economics', *California Law Review*, 1051-1144.
- Lee, D.S. and J. McCrary (2006), 'Crime, Punishment, and Myopia', NBER Working Paper 11491.
- Motta, M. and M. Polo (2003), 'Leniency programs and cartel prosecution', *International Journal of Industrial Organization*, **21**(3), 347-379.
- Normann, H. and R. Ricciuti (2009), 'Laboratory Experiments for Economic Policy Making', *Journal of Economic Surveys*, **23**(3), 407-432.
- Office of Fair Trading (2012), 'OFT's guidance as to the appropriate amount of a penalty', OFT423 Press Release, 1-26.
- Office of Fair Trading (2013), 'Office of Fair Trading Annual Plan 2013-14', OFT1462 Press Release, 1-20.
- Polinsky, A.M. and S. Shavell (1979), 'The optimal tradeoff between the probability and magnitude of fines', *American Economic Review*, **69**(5), 880-891.
- Polinsky, A.M. and S. Shavell (2000), 'The Economic Theory of Public Enforcement of Law', *Journal of Economic Literature*, **38**(1), 45-76.
- Simon, H.A. (1955), 'A Behavioral Model of Rational Choice', *Quarterly Journal of Economics*, **69**(1), 99-118.
- Spagnolo, G. (2000), 'Self-Defeating Antitrust Laws: How Leniency Programs Solve Bertrand's Paradox and Enforce Collusion in Auctions', FEEM Working Paper, 52.
- Spagnolo, G. (2004), 'Divide et Impera: Optimal Leniency Programs', CEPR Discussion Paper, 4840.
- Spiegler, R. (2011), *Bounded Rationality and Industrial Organization*, Oxford University Press.
- Stigler, George. J. "The optimum enforcement of laws", *Journal of Political Economy*, **78**, 343-355, (1970)
- The Economist (2012), 'Fine and Punishment', accessed on 30/01/2017 at <http://www.economist.com/node/21559315/print>
- Tversky, A. and D. Kahneman (1992), 'Advances in prospect theory: Cumulative representation of uncertainty', *Journal of Risk and uncertainty*, **5**(4), 297-323.

Appendix A - Additional Results on Asking Price

One may argue that the experimental design allows firms to tacitly collude to avoid detection, which would make it impossible to discuss consumer welfare. If firms were indeed tacitly colluding, one would expect no significant difference between asking prices within and outside of a cartel. We address this by investigating the asking price, the average of the three stated prices in a given market in a particular period. Table 9 yields the asking prices for all treatments, and distinguishes between the price charged in rounds with and without a cartel.¹⁵ At a first glance, three main insights emerge from that table: (i) prices do not appear different when varying detection probability and magnitude of fines, (ii) but they appear higher in collusive than in competitive markets; and (iii) it is not obvious if prices are substantially different given the presence or absence of a leniency policy.

Table 9: Asking prices – Average (Std. Dev.) per treatment.

Probability	Fine	<u>Collusive</u>		<u>Competitive</u>	
		Without leniency	With leniency	Without leniency	With leniency
10%	8	95.75 (2.90)	97.89 (2.10)	93.81 (1.92)	92.56 (1.59)
20%	4	95.66 (2.11)	98.06 (2.90)	92.36 (0.86)	93.01 (1.08)
Baseline		96.23 (2.69)		95.96 (2.44)	

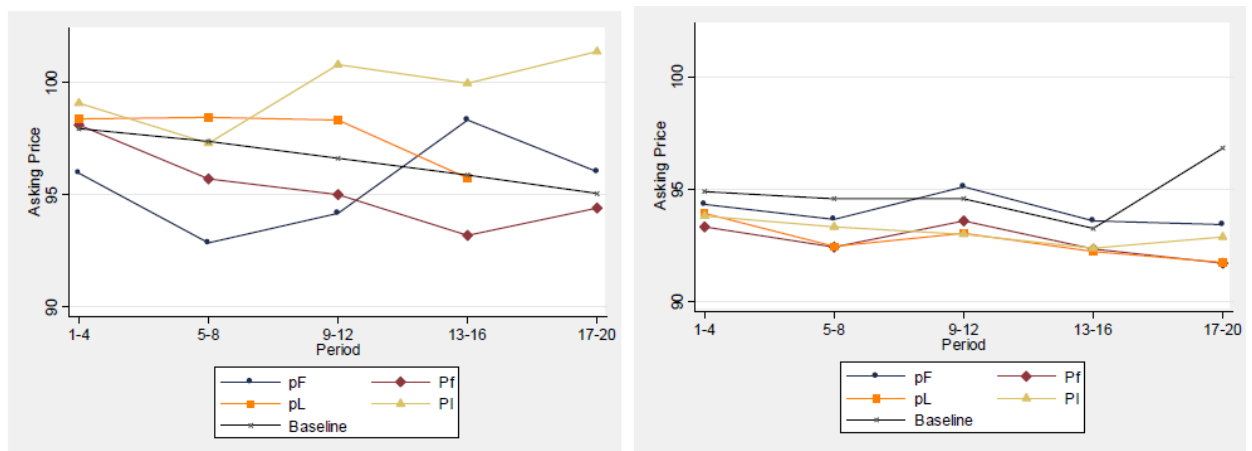
Note: Asking prices are calculated as the average of the three stated prices in a market.

It is important to notice that there exists a clear gain from colluding, as asking prices are between 3 and 4 points higher in collusive than in competitive markets. These findings appear all the more remarkable as the gain from colluding exists even though the cartel agreement was not

¹⁵ Arguably, subjects will self-select into collusive and competitive markets. A pairwise comparison of asking prices without distinguishing between collusive and competitive markets reveals no statistically significant difference between prices with leniency. Absent leniency, prices are higher if fines are high and detection rates are low.

binding, and no actual communication by means of, for example, a chat took place. Further, we observe that asking prices from competitive markets are not statistically different across treatments (Kruskal-Wallis test, $p > 0.1$). This is intuitive, as absent collusion firms face identical decisions across our treatments. There is however mild statistical evidence that asking prices are different for collusive markets (Kruskal-Wallis test, $p = 0.09$). This in fact supports the findings of Bigoni et al. (2012), who report statistically higher prices inside, but not outside of cartels. The difference can be observed when we compare the price dynamics over time. Figure 5 depicts the per-period average asking prices for collusive and competitive markets. The figure reveals a tendency for more dispersed prices in collusive markets, while prices in competitive markets move almost parallel with little differences over time.

Figure 5: Asking prices for collusive (Left) and competitive (Right) markets.



Turning to statistical tests, for which we focus only on collusive markets, we compare the asking price with and without leniency. We find that asking prices are about 2 points higher in the presence of leniency, and this difference is statistically significant (Mann-Whitney test, $p = 0.01$). Higher cartel prices in treatments with leniency are also reported in Bigoni et al. (2012), who emphasize that in the presence of a leniency program firms undercut the agreed-upon price and self-report. Hence, punitive price-war will occur in competitive markets, while absent leniency the price war might take place within the cartel. A similar reasoning can be applied to our experimental design, which may artificially inflate prices in treatments with leniency.

In the next step, we check if this effect of leniency also exists independent of the fine-detection ratio. We find no statistically significant difference between the asking prices pF and pL , but for high detection rates and low fine there is mild evidence of a statistical difference between Pf and Pl (Mann-Whitney test, $p=0.08$). A more detailed comparison shows that the difference between low detection rates and high detection rates is neither statistically significant for pL vs. Pl , nor for a comparison between pF and Pf . In other words, our analysis provides no statistical support for the suggestion that firms react to higher fines by raising their asking prices. We, hence, conclude that fine and detection ratios are indeed substitutable with respect to their effect on asking prices.

Appendix B - Instructions

Welcome and thank you for taking part in this experiment. In this experiment you can earn money. How much money you will earn depends on your decision and on the decision made by other participants in this room.

The experiment will proceed in two parts. The currency used in Part 1 of the experiment is Pound Sterling (GBP). The currency used in Part 2 is experimental points. Each experimental point is worth 15 pence. All earnings will be paid to you in cash at the end of the experiment.

Every participant receives exactly the same instructions. All decisions will be anonymous.

It is very important that you remain silent. If you have any questions, or need assistance of any kind, please raise your hand and an experimenter will come to you.

Instructions for Part 1

In the first part of the experiment you will be asked to make 15 decisions. For each line in the table in the next page there is a paired choice between two options ("Option A" and "Option B"). Only one of these 15 lines will be used in the end to determine your earnings. You will only know which one at the end of the experiment.

Each line is equally likely to be chosen, so you should pay equal attention to the choice you make in every line. At the end of the experiment a computerized random number (between 1 and 15) determines which line is going to be paid.

Your earnings for the paid line depend on which option you chose: If you chose option A in that line, you will receive £1. If you chose option B in that line, you will receive either £2 or £0. To determine your earnings in the case you chose option B there will be second computerized random number (between 1 and 20).

Instructions for Part 2

In this part of the experiment you will form a group with two other randomly chosen participants in this room. Throughout the experiment you are matched with the same two participants. All groups of three participants act independently of each other.

This part of the experiment will be repeated at least 20 times. From the 20th round onwards, in each round there is a one in five (20%) chance that the experiment will end.

Instruction:

You are in the role of a firm that is in a market with two other firms.

In each round, you will have to choose a price for your product. This price must be one of the following prices:

90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102.

You will only sell the product if your price is the lowest of the three prices chosen by you and the other two firms in that round. If you sell the product, your earnings are equal to the difference between the price and the cost, which is 90:

Earnings = Price -- 90.

If you do not sell the product, you will not get any earnings but you do not have costs either. If two or more firms sell at the same lowest price, the earnings will be shared equally between them. After your price choice, you will be told whether you have selected the lowest price as well as the price of the other firms. Before you choose your price, you can decide to agree with the other firms to set the highest price of 102 and share the earnings. This agreement is only valid if all three firms want to agree on it. However, the price agreement is not binding and firms are not required to set the agreed price.

The price agreement may be discovered by the computer. In that case, a fine of 8 points has to be paid. The computer can detect it in one out of 10 cases (a chance of 10%).

A price agreement remains valid -- and can be discovered-- as long as it has not been discovered in a previous round. Once this has happened, you will not be fined in the future, unless you make a price agreement again.

At the end of each round, you will be told

- the earnings you made in this round
- in case you agreed on a price if this agreement has been detected.

Final Payment:

At the beginning of the experiment you start with an initial endowment of 40 points = 6 GBP. The earnings you earned in each round minus any fine that you paid will be converted into cash. Each point is worth 15 pence, and we will round up the final payment to the next 10 pence. We guarantee a minimum earning of 2 GBP.